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INTERNATIONAL DEVELOPMENT RESEARCH CENTRE

CENTRE DE RECHERCHES POUR LE DEVELOPPEMENT INTERNATIONAL

ENERGY RESEARCH IN DEVELOPING COUNTRIES: GUIDELINES FOR AN IDRC RESPONSE

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29.

Energy Research in Developing Countries: Guidelines for an IDRC Response

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Preface

The purpose of this report is:

- to describe the central issues and requirements relating both to policy research and technical research in the energy sector of developing countries.
- to consider the activities of other donors in the field.
- to advise the Centre on how it might utilise an increase in funds for energy related research.

The report is divided into four main sections: in the first, the main energy problems facing developing countries are described; in the second section the various responses to these problems are outlined in terms of general principles; in the third section, the main actions of the aid agencies are summarised; and in the fourth section consideration is given to the questions of energy research in developing countries from the point of view of the aid agencies, the developing countries themselves, and the general principles which might guide the future course of IDRC assistance to the field.

The report was produced between the middle of March and the beginning of July 1981 and was based on a review of literature and discussions with the Staff of IDRC, other bilateral and multilateral aid donors and a very limited number of interviews with researchers from developing countries (see Annex I).

Summary of the Main Arguments and Conclusions

The energy problems of the Third World are as diverse as the countries themselves. But at the most general level there are two distinct elements: problems associated with the rise in oil prices and problems associated with the supply of the fuels traditionally used by rural people, such as fuelwood, crop residues, and dung.

The oil price rises largely affect the modern industrial sectors and exacerbate the problems of underdevelopment associated with foreign exchange balances, international indebtedness and the resources available for development. The direct effects on oil-using industry and transport can be severe and have many similarities with the problems facing industrialized countries.

In welfare terms, rural energy problems are possibly even more severe than those of the industrial sector; with over half the world's propulation said to derive its inanimate energy from the largely uncommercialized biomass of fuelwood, crop residues, and dung. Details of these problems are still scarce and unreliable; but a picture is emerging of the complexity of rural energy needs and of the immensity of the problem: 100 million people are thought to have insufficient fuelwood to meet even their minimum needs and a further 1000 million are likely to be in a similar position by the year 2000. Shortages of oil limit the possibilities of rural development, both directly (through the lack of fertilizer, irrigation and transport)and indirectly(through lack of foreign exchange and the high cost of imports).

The policy options facing developing countries include increasing the supply of primary energy, increasing the efficiency with which existing sources of energy are utilized, and more effectively managing the demand for energy. The demand for energy is strongly influenced by the pattern of development, the distribution of income, and the style of living. However, whatever efforts are made, the oil needs of all sectors of developing countries will increase substantially over the next 20 years.

The response of developing countries takes place in a world context in which the bulk of research and development is carried out in developed countries and is orientated to the problems of these countries, where the transfer of technology between countries often takes place under conditions of intense bargaining between unequal parties, and where financial resources are already severely constrained both nationally and internationally.

Much of the energy related technology likely to be applied in developing countries until the turn of the century is already well known. The major constraints are likely to be associated with the "software". The research problem facing most Third World countries will, therefore, be a problem of identifying the precise form of their various energy problems, identifying the various options open to them, evaluating and adapting these options in the context of local needs and conditions, developing local production capabilities and implementing programmes of action. Much of this research can only be done in developing countries and much of it will be done best by local people with knowledge of local conditions.

The energy related activities of the aid donors have recently been reviewed in a number of reports. Most donors are attempting to reorganize their programmes to be more responsive to developing country requirements; however, actual expenditures continue to be concentrated on large scale electricity generation and distribution.

Information on aid activity relating to energy research is less accessible. No analyses have yet been found which show expenditures for the various types of energy research, nor the extent to which researchers in developing countries are involved. Two authoritative sources (IBRD and UNERG) suggest that most research is being carried out in developed countries or is controlled by expatriates. Many bilateral aid programmes are associated with the promotion and export of their own country's energy technology.

Energy research in developing countries has expanded rapidly during the 1970s. In so far as a pattern can be percieved from the fragmentary evidence available, it appears that much of the existing research is: concentrated on so-called new and renewable sources of energy (though oil and other mineral exploration is an exception); it is often isolated from existing scientific knowledge, and from the processes of energy planning, production and implementation; it tends to stress technological aspects to the exclusion of the social and economic aspects that affect viability and the rate of diffusion; and there is a marked absence of rigorous testing of energy devices under genuine operating conditions.

The IDRC response should be guided by four principles:

(i) The Centre should concentrate on those types of support which distinguish its assistance from that of other donors; it should respond to the priorities percieved by people in the Third World; and its independence from national or commercial interests should be emphasized and maintained.

(ii) It should focus on those research areas which are best carried out by Third World nationals in their own countries; particularly those areas of research that increase the countries' ability to identify problems and choose between alternatives.

(iii) It should encourage a problem orientated, multidisciplinary approach.

(iv) Because of the lack of knowledge about existing research activity and likely future needs, the Centre should adopt a consciously flexible approach to its funding which can adapt to the changing situation. This will initially require a wide definition of what constitutes research and the utilisation of a range of outside expertise.

There does appear to be a demand from developing countries for the type of assistance that IDRC can provide for energy research, and this demand might be expected to eventually justify expenditures at the level of existing programmes. The rate at which funds could initially be disbursed would be limited by the speed with which adequate staff were made available.

Consideration of these issues suggests that there are three areas of research that are both required by developing countries and for which IDRC's style of operation is well suited. These are described on pages 31 - 33 and cover:

a. Research to identify and specify energy problems

b. Research to identify and evaluate energy technology

c. Research for energy planning.

d) new energy or different energy as inputs

Policy only

Whatever scale of funding is made available a first step would be to improve the state of knowledge of current research activity and future need by the methods conventionally used by the IDRC in developing its other programmes. But because of the extent of the gap in knowledge there is a pressing need to commission some form of 'research on research' both to guide IDRC's activities and to assist the development of energy R and D policies in other agencies and in developing countries.

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Members of IDRC's Social Science Division
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*Recipients of the draft report who had no opportunity for comment.

Annex I

Alphabetical List of People and Organisations Consulted in the Preparation of this Study

Mr. Barnea, UNITAR, New York.
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Tom Lawand, Brace Research Institute, Montreal.
Gill Lessard, Forestry Advisor, AFNS, IDRC.

Table 5 (ii)

ODA and Non-Concessional Commitments for Energy Development,
by individual Multilateral Institutions and Energy Sub-Sectors, 1979

($ million)

Sub-Sector \ Multilateral Institutions	ODA					Non Concessional				
	Total	World Bank	IDB	ASDB	AFDB	Total	World Bank	IDB	ASDB	AFDB
I. Overall Energy Planning(1)	-	-	-	-	-	-	-	-	-	-
II. Energy Conservation	-	-	-	-	-	-	-	-	-	-
III. Resource Survey	-	-	-	-	-	-	-	-	-	-
IV. Oil	67.0	67.0	-	-	-	277.0	277.0	-	-	-
1. Predevelopment(2)	-	-	-	-	-	-	-	-	-	-
2. Oil production	30.0	30.0	-	-	-	-	-	-	-	-
3. Associated transport and storage	-	-	-	-	-	-	-	-	-	-
4. Refineries	-	-	-	-	-	-	-	-	-	-
5. Oil-fired power plants	37.0	37.0	-	-	-	277.0	277.0	-	-	-
V. Gas	-	-	-	-	-	75.0	75.0	-	-	-
1. Predevelopment(2)	-	-	-	-	-	-	-	-	-	-
2. Gas production	-	-	-	-	-	75.0	75.0	-	-	-
3. Associated transport and storage	-	-	-	-	-	-	-	-	-	-
4. Gas-fired power plants	-	-	-	-	-	-	-	-	-	-
VI. Coal	200.0	200.0	-	-	-	340.1	130.0	-	204.4	5.7
1. Predevelopment(2)	-	-	-	-	-	-	-	-	-	-
2. Coal production	-	-	-	-	-	39.0	-	-	39.0	-
3. Associated transport and storage	-	-	-	-	-	5.7	-	-	-	5.7
4. Coal-fired power plants	200.0	200.0	-	-	-	295.4	130.0	-	165.4	-
5. Synthetic fuel production	-	-	-	-	-	-	-	-	-	-
VII. Nuclear										
VIII. New and Renewables	120.3	18.3	77.0	24.0	-	929.2	366.0	502.5	60.7	-
1. Predevelopment(2)	-	-	-	-	-	-	-	-	-	-
2. Hydro	115.8	14.8	77.0	24.0	-	929.2	366.0	502.5	60.7	-
of which:										
(a) large (over 1 mW)	(115.8)	(14.8)	(77.0)	(24.0)	-	(929.2)	(366.0)	(502.5)	(60.7)	-
(b) mini	-	-	-	-	-	-	-	-	-	-
3. Solar	-	-	-	-	-	-	-	-	-	-
4. Biogas	-	-	-	-	-	-	-	-	-	-
5. Fuelwood and charcoal	4.5	4.5	-	-	-	-	-	-	-	-
6. Alcohol	-	-	-	-	-	-	-	-	-	-
7. Peat	-	-	-	-	-	-	-	-	-	-
8. Geothermal	-	-	-	-	-	-	-	-	-	-
9. Oil shale and tar sands	-	-	-	-	-	-	-	-	-	-
10. Wind	-	-	-	-	-	-	-	-	-	-
11. Ocean	-	-	-	-	-	-	-	-	-	-
12. Drought animal power	-	-	-	-	-	-	-	-	-	-
13. Other	-	-	-	-	-	-	-	-	-	-
IX. Power Transmission and Distribution	273.6	219.5	9.2	29.9	15.0	389.6	300.0	50.0	-	39.6
Of which: rural electrification	202.1	175.0	9.2	11.3	6.6	-	42.0	-	-	12.5
X. Unspecified	-	-	-	-	-	-	-	-	-	-
XI. Total	660.9	505.8	86.2	53.9	15.0	2010.9	1148.0	552.5	265.1	45.3

(1) Including supply and demand management, research, institution building, training, extension services, etc.
(2) Including exploration, feasibility studies, testing, etc.

Source; OECD DCD/81.3(Ist Rev) 27th May 1981 page 10

Table 5 (

ODA COMMITMENTS FOR ENERGY DEVELOPMENT BY INDIVIDUAL DAC MEMBERS AND ENERGY SUB-SECTORS, 1979

($ million)

SUB-SECTOR \ DAC MEMBERS	AUSTRALIA	AUSTRIA	BELGIUM	CANADA	DENMARK	FINLAND	FRANCE	GERMANY	ITALY	JAPAN	NETHERLANDS	NEW ZEALAND	NORWAY	SWEDEN	SWITZERLAND	UNITED KINGDOM	UNITED STATES	E.E.C.	TOTAL
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
I. Overall Energy Planning(1)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
II. Energy Conservation	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9.8		9.8
III. Resource Survey	-	-	-	-	-	-	0.8	-	-	-	-	-	-	-	-	-	-	-	0.8
IV. Oil	0.3	0.2	-	13.8	-	-	-	1.3	-	56.1	0.2	-	0.8	-	-	4.4	-	3.4	80.5
1. Predevelopment(2)	-	-	-	1.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.0
2. Oil Production	-	0.2	-	12.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13.0
3. Associated transport and storage	0.3	-	-	-	-	-	-	1.3	-	4.1	-	-	0.8	-	-	-	-	3.4	9.9
4. Refineries	-	-	-	-	-	-	-		-	-	0.2	-	-	-	-	-	-	-	0.2
5. Oil-fired power plants(*)	-	-	-	-	-	-	-	-	-	52.0	-	-	-	-	-	4.4	-	-	56.4
V. Gas	-	-	-	-	-	-	-	-	-	-	3.0	-	-	-	-	5.2	-	-	8.2
1. Predevelopment(2)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2. Gas Production	-	-	-	-	-	-	-	-	-	-	3.0	-	-	-	-	-	-	-	3.0
3. Associated transport and storage	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4. Gas-fired power plants(*)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.2	-	-	5.2
VI. Coal	-	4.0	-	-	7.6	-	10.9	196.8	-	-	-	-	-	-	-	44.0	-	-	263.3
1. Predevelopment(2)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2. Coal Production	-	-	-	-	-	-	-	14.2	-	-	-	-	-	-	-	-	-	-	14.2
3. Associated transport and storage	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4. Coal-fired power plants	-	4.0*	-	-	7.6*	-	10.3	182.6	-	-	-	-	-	-	-	44.0	-	-	248.5
5. Synthetic Fuel production	-	-	-	-	-	-	0.6	-	-	-	-	-	-	-	-	-	-	-	0.6
VII. Nuclear	-	-	-	-	-	-	1.7	-	-	16.1	-	-	-	-	-	-	-	-	17.8
1. Of which: uranium mining	-	-	-	-	-	-	1.7	-	-	16.1	-	-	-	-	-	-	-	-	17.8
VIII. New and Renewables	0.4	-	-	5.0	-	-	12.9	6.1	-	281.1	2.1	-	9.6	9.1	-	215.5	-	-	541.8
1. Predevelopment(2)	0.1	-	-	0.7	-	-	2.4	0.7	-	-	-	-	0.4	-	-	-	-	-	4.3
2. Hydro	0.3	-	-	4.3	-	-	8.9	5.4	-	281.1	-	-	9.2	8.9	-	219.4	-	-	533.5
of which:																			
(A) Large (over 1MW)	-	-	-	(4.3)	-	-	(7.5)	(5.4)	-	(281.1**)	-	-	(8.2)	(8.9)	-	(212.2)	-	-	(527.6)
(B) Mini	(0.3)	-	-	-	-	-	(1.4)	-	-	-	-	-	(1.0)	-	-	(3.2)	-	-	(5.9)
3. Solar	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4. Biogas	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5. Fuelwood and charcoal	-	-	-	-	-	-	1.1	-	-	-	2.1	-	-	0.2	-	0.1	-	-	3.5
6. Alcohol	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7. Peat	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8. Geothermal	-	-	-	-	-	-	0.5	-	-	-	-	-	-	-	-	-	-	-	0.5
9. Oilshale and tar sands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10. Wind	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11. Ocean	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12. Draught Animal Power	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13. Other	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
IX. Power Transmission and Distribution	1.9	-	-	149.8	11.9	-	28.5	151.4	-	37.2	34.8	1.6	3.1	3.6	1.3	3.1	66.6	6.7	507.3
1. Of which: rural electrification	-	-	-	20.4	-	-	1.0	22.9	-	-	24.7	-	-	1.6	-	-	66.6	-	137.2
X. Unspecified	-	-	-	-	-	-	19.2	8.2	-	-	-	-	-	-	-	-	(135.0)	-	(162.4)
TOTAL ENERGY	8.6	4.2	-	168.6	19.5	-	74.0	363.8	-	390.5	40.1	1.6	13.5	12.7	1.3	272.2	211.4	10.1	1592.1

(1) Including supply and demand management, research, institution building, training, extension services, etc.
(2) Including exploration, feasibility studies, testing, etc.
(*) Oil-fired power plants may include amounts for gas fired power plants, where the latter are not specifically mentioned.
(**) Of which $100.6 for power generating barges.

Source: OECD DCD/81.3 (1st Rev) 27th May 1981 page 8.

Table 4.

CURRENT AND DESIRABLE WORLD BANK ENERGY LENDING PROGRAMS, FY 1981-85

(Million current US dollars)

	Current		Desirable	
	Lending Program	Total Project Cost	Lending Program	Total Project Cost
Coal and Lignite /a	840	4,270	2,000	7,350
Oil and Gas				
Predevelopment	1,020	2,610	2,410	5,850
Oil Development /b	1,755	5,900	3,320	12,150
Gas Development /c	1,210	3,250	2,270	5,875
	3,985	11,760	8,000	23,875
Refineries	150	400	1,000	3,100
Renewables				
Fuelwood	425	850	1,100	2,200
Alcohol	200	2,100	650	4,550
	625	2,950	1,750	6,750
Electric Power	7,590	37,950	11,000	47,450
Industrial Retro-fitting	0	0	1,250	3,825
TOTAL	13,190 /d	57,330	25,000 /d	92,350
Bank Share of Total Project Cost (percent)		23		27

/a Includes coal gasification projects.
/b Includes heavy oil projects.
/c Includes methanol.
/d Does not provide for any lending to China.

Source: World Bank 1980

Table 3.
Summary of Aid Finance to the Energy Sector of Developing Countries
(millions current US dollars)

		1978	1979/80
World Bank Group[1]			$3,005
OECD Bilateral[2]	oda	$972	$1,434
	non-oda	$5259	/$4,976/
Regional Development Banks[3]			
	oda		$ 659
	non-oda		/$1545/
OPEC[3]		$850	$ 530
Total oda and multilateral assistance			$5,628[4]

Notes

1. Source:World Bank 1980
2. Source: OECD Report DCD/81.3 Feb 1981
3. Source: UNERG panel report on finance A/CONF/100/PC/29 19 Jan 1981
4. The total of $5,600 is given by the World Bank as covering all commitments of official development assistance and loans from the mulilateral agencies (World Bank 1980 para 1.10). However it is not clear what account has been taken of expenditures through the UN system.

Table 2

AN ENERGY CLASSIFICATION OF DEVELOPING COUNTRIES

	NET OIL EXPORTING DEVELOPING COUNTRIES		OIL IMPORTING DEVELOPING COUNTRIES[a]				
NET OIL IMPORTS AS % COMMERCIAL ENERGY DEMAND[b]	OPEC Members	Non-OPEC	0-25%	26-50%	51-75%	76-100%	
	ALGERIA	*BAHRAIN*	*ARGENTINA*	*CHILE*	*ALBANIA*	Bahamas	Mauritius
	GABON	*BOLIVIA*	*COLOMBIA*	Mongolia	*BRAZIL*	*BARBADOS*	Nicaragua
	IRAN	*MALAYSIA*	Korea, Dem. Rep.	*YUGOSLAVIA*	Korea, Rep. of	Costa Rica	Panama
	IRAQ	*MEXICO*	*ROMANIA*		Lebanon	*CUBA*	Papua New Guinea
	KUWAIT	*OMAN*	South Africa		*TURKEY*	Cyprus	Paraguay
	LIBYA	*PERU*				Dominican Rep.	Portugal
	QATAR	*SYRIAN ARAB REP.*				Fiji	Suriname
	SAUDI ARABIA	*TRINIDAD AND TOBAGO*				*GUATEMALA*	Uruguay
	UNITED ARAB EMIRATES	*TUNISIA*				Guyana	
	VENEZUELA					Ivory Coast	
						Jamaica	
						Jordan	
						Malta	
COUNTRIES WITH ACTUAL OR POTENTIAL FUELWOOD PROBLEM[c]							
	ECUADOR	*ANGOLA*	*INDIA*	*BANGLADESH*	*AFGHANISTAN*	Benin	Mauritania
	INDONESIA	*BURMA*	Viet Nam,	Botswana	Burundi	Bhutan	*MOROCCO*
	NIGERIA	*CHINA*	Zimbabwe	Mozambique	*GHANA*	*CAMEROON*	Nepal
		CONGO, PEOPLE'S REP.		*PAKISTAN*	Malawi	Cape Verde Is.	Niger
		EGYPT		Zambia	Rwanda	Central African Rep.	*PHILIPPINES*
		ZAIRE				Chad	Sao Tome and Principe
						Comoros	Senegal
						El Salvador	Sierra Leone
						Eq. Guinea	Solomon Is.
						Ethiopia	Somalia
						Gambia, The	Sri Lanka
						Grenada	Sudan
						Guinea	Swaziland
						Guinea-Bissau	Tanzania
						Haiti	*THAILAND*
						Honduras	Togo
						Kampuchea, Dem.	Uganda
						Kenya	Upper Volta
						Lao PDR	Western Samoa
						Lesotho	Yemen Arab Rep.
						Liberia	Yemen PDR
						Madagascar	
						Maldives	
						Mali	
POPULATION (IN MILLIONS)							
	320	1180	820	210	245	395	

Countries shown in *ITALICS* are oil and/or gas producers. Table based on UN World Energy Statistics 1978 (except for Bhutan, Botswana, Lesotho and Swaziland whose position in the Table is estimated) and staff estimates of fuelwood situation. Population data from World Development Report, 1980 roundad to nearest 5 million.

a/ Excluding countries with 1978 per capita GNP above $3000 and countries with populations of less than 0.5 million that are not members of the World Bank.

b/ Imports 1978

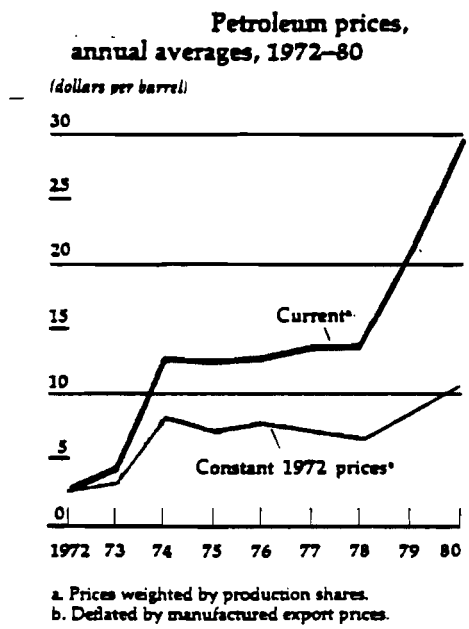
c/ Countries were placad in this category if estimated annual consumption of fuelwood could not be sustained through the year 2000, without damage to the ecology, at a level of 0.75 m^3 per capita where income per head (in 1978) was below $300, falling linearly to 0.50 m^3 at $600 and zero at $900. Many countries not included in this group have or will have fuelwood problems in local areas.

Source: World Bank 1980 page 5.

Table 1.
Oil Price Changes 1972-1980

	In current US$	In constant 1970 US$
1972	2.1	1.6
1973	2.8	2.0
1974	11.1	6.1
1975	10.8	5.1
1976	11.6	5.5
1977	12.6	5.5
1978	12.9	4.7
1979	17.6	6.1
1980 1st half	20.3	6.8
1980 2nd half	29 - 32	9.7 - 10.7

Source: Asian Development Bank, Regional Energy Survey March 1981 page 218



Source: World Bank 1980

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'authoritative' reviews of particular areas of research (energy planning approaches and the methodological problems of rural energy surveys, being among the prime candidates); or it might be a more regular activity of monitoring energy research in specific fields in consultation with groups of eminent researchers. A model for this latter activity might be the IDRC support for the Research Review and Advisory Group in Education (RRAG).

C. Research for Energy Planning

The third category of research includes a range of research issues that specifically provide the underpinning to energy sector planning. One group of issues directly complements the previous category by identifying the largely non-technical policy options associated with the management of energy demand and supply. Such research might include energy pricing studies; studies of energy conservation policy; studies of the energy implications of different strategies for transport, industrialisation, agriculture, rural development, urbanisation; studies of the relationship between energy and nutrition, energy and employment, energy and trade and so forth. Research would also be included in this category on the policies associated with the development of the range of energy supplies: energy investment policy; fuel import policy; exploration policy; resource depletion policy; and policy towards the importation of energy conversion and utilizing technology.

A second group of research issues involves the development of a strategy for energy research and development; and the development of local capabilities for research, planning, negotiation, manufacture, implementation, and training in the energy sector.

The next steps

The major direction of an expanded energy programme within IDRC will be largely determined by the scale of funds allocated to the activity and to the administative arrangements that are made - two issues that are outside the terms of reference of this report. But is the general principles of this report are accepted there is no need for any expanded programme to represent a major departure from current IDRC procedures nor from the types of energy related research that are currently supported. Current energy research support is concentrated on the fuelwood sector and energy policy studies (largely in the form of social and economic evaluations of small scale energy technology and surveys of current energy use in rural areas). Other energy research has been undertaken from time to time as part of the main activity of existing divisions: small scale methane production related to the disposal of human waste; wind power in relation to the pumping of drinking water; energy information systems; and the training of energy researchers through the Human Resources Division. An expanded programme could initially be built on existing capabilities.

It appears that there is a demand for the type of assistance that IDRC could provide to energy research in developing countries and that such a programme could be built up to the level of other existing IDRC programmes over a number of years. Initially the main determinant of the speed at which a programme could be developed would be the number of IDRC staff involved.

Whatever the size of the programme and its ultimate form there is one task which stands out as being an essential first step: as the review has shown there is a pressing need for "research on research"; this need derives not just from the requirements of IDRC to know what is going on but it also derives from the needs of any country or aid agency developing a more co-ordinated approach to energy research and development. Such an activity could take many forms and might be done alone or in association with other donors. It might range from the commissioning of a series of

anticipated demand should be met; but in future it is likely that a more interventionists policy will have to be pursued in many countries, in which some types of demand are encouraged at the expense of others; it is likely, for instance, that the need for commercial energy supplies will form a binding constraint on the implementation of many industrial and agricultural development strategies currently being contemplated and therefore different strategies will have to be considered. Research would often be required to determine what research had already been carried out and to improve the research methods currently used. There would be a need to develop a research strategy which combined rapid appraisals (which form the bulk of current research) with longer term analysis of changes.

The nature of energy problems also requires an understanding of the energy resources that are likely to be available. IDRC's assistance might best be focussed on the assessment of the energy resources available to rural populations, particularly in respect to the biomass. There is also a pressing need to determine the extent of fossil fuel and hydro potential in many countries, but the high cost of such research is likely to restrict IDRC's ability to respond. However, a limited role might involve support for research to improve the knowledge required by developing countries when negotiating exploration contracts with foreign firms.

B. Research to identity and evaluate energy technologies

For most developing countries, the problem of implementing effective energy policies will not require research to generate fundamentally new knowledge. The main task will be to identify and review what is already known, to evaluate this knowledge in comparison with other options and in relation to the country's needs and local circumstances; and, where this knowledge is embodied in hardware, to adapt it to the requirements of local manufacture and use.

Many of the energy research proposals that are likely to be received by IDRC will be associated with technical research on particular energy conversion and utilisation devices. IDRC should discriminate between such research not only on the grounds of cost (for some of this research can be expected to be very costly) but also on the grounds of: (i) whether the research represents a genuine comparison of a range of options under actual operating conditions, (ii) whether an attempt is made to match the technology to a known set of social, economic and technical requirements, (iii) whether the results are likely to be independent and authoritive, and, (iv) whether a sufficiently multidisciplinary approach is adopted that takes into account the social, economic and technical aspects of the problem.

It is expected that a large proportion of the projects in this category will be associated with the evaluation of small scale technologies for predominantly rural application. But in a significant number of countries there would also appear to be a need for independent research on the relative merits of the larger systems - particularly nuclear, large scale ethanol and large scale rural electrification schemes. This research would not involve the testing of the devices themselves but would rather be based on the analysis of information culled from existing sources.

Existing literature on the evaluation of energy technologies under genuine operating conditions is often inadequate and there is a need for an improvement in the research methods and some agreement about the form in which such analyses are presented in order to facilitate realistic comparisons.

The areas where research funding is required will best be identified through those procedures that IDRC has previously followed in the development of existing programmes: consultation with researchers and policy makers; the evaluation of proposals by knowledgable people; the monitoring of research publications; and the commissioning of systematic 'research on research'. However, the speed with which such a programme could be developed will very much depend not only on the capacity of developing countries to absorb funds, but also on the ability of the Centre to recruit adequate staff. This may impose a very real constraint as all the agencies interviewed suggested that lack of skilled manpower was a major limitation on their own activities; this was said to be especially the case in Canadian Ministry of Energy Mines and Resources, and the Canadian National Research Council).

The earlier sections of this report suggest that there is initially a need for research across the range of energy problems and not, for instance, just in the area of new and renewable sources of energy or in energy economics. If restrictions have to be made, they are perhaps better made in terms of an assessment of the likely beneficiaries of the research and the likelihood of the research leading to effective assistance to the mass of the people rather than by the demarcation of specific topics or specific technologies. However, the earlier analysis implies that even such an equity criterion might be unproductively restrictive, given that the energy problems of poor people are directly linked to the energy use of other sections of the society; for example, a possible option for meeting the energy needs of agriculture may be through the restriction of energy use by sections of the urban population.

From what has been said so far, four areas of research stand out as being particularly appropriate for IDRC support.

A. Research to identify and specify energy problems

The first priority is for developing countries to develop the capability to understand the nature of the energy problems they face. From such research all other policies and actions follow. The clear identification of the casual relations associated with a particular problem enable actions to be taken at the point most likely to produce effective results. It enables solutions to be sought for particular problems rather than, as commonly occurs at the moment, problems being sought which are thought to be suitable for a particular technology. It provides a basis for making decisions about the allocation of research and development resources, the management of energy supply and demand, the allocation of investment, and the specification of aid requirements. The independence of developing countries requires that they undertake this research themselves and that they determine the significance of each problem. It is also likely that as this kind of research necessitates a detailed knowledge of local conditions the research will be best done by local people.

The research that is required would cover the range of topics from the 'macro' analysis of the energy supply and demand prospects facing the whole economy, through the analysis of the requirements of particular sub-sectors and regions, to the 'micro' analysis of the current energy use pattern and future requirements of particular social groups, such as rural energy surveys. The studies to determine the energy needs of rural populations are particularly relevant, given the current lack of knowledge of energy resources which do not enter the cash economy and the critical function that understanding users' needs plays in the introduction of technical change in subsistence economies. Much previous analysis of energy demand has assumed that the

to evaluate it in their own environment, and adapt it to their own advantage.

This emphasis on creating the capacity to choose and the reliance on proven options is shared by a number of authorities. Weiss and others, at the World Bank, suggest that in the field of new and renewable sources of energy at least "a major problem facing planners and prospective users of these renewable energy technologies is that of making informed choices among competing processes and equipment" (1980 para. 3.20) ..... "developing countries would derive major benefits.....from building technological capacity..... to assess needs and resources and to choose, adapt, create and diffuse renewable energy technology suited to their needs"(p. i). Similar views are held by the OECD (1979, p. 28), Bartlem and Hoffman (1980, p. 126), UNERG (1981).

A multidisciplinary approach to problems

The third principle which emerges from the discussion is that any IDRC programme should be multidisciplinary in its approach. This results from the focus on problems and needs rather than a focus on particular technologies. The capabilities necessary to identify energy problems and to make choices between competing options require that the skills of science and technology are effectively combined with the financial, economic and sociological perspective of the social sciences. However, such integration between the disciplines is often difficult to achieve. Existing energy research appears to be largely within the confines of a single traditional discipline, such as engineering, forestry or economics; furthermore the institutional structure within IDRC has had a tendency to reinforce such divisions.

A wide definition of 'research'

Much of the energy research that is currently most crucially required is likely to involve the application of known procedures in new locations, rather than the generation of fundamentally new knowledge. Research is required to increase knowledge of conditions within each country, to determine the range and characteristics of technology, to obtain know-how and to understand what is already known elsewhere. This research will not necessarily be 'academic' or be confined to the activities of research laboratories. Such a wide range of activities is encompassed in IDRC's charter and would allow the Centre to meet a need in the energy sector that is denied other agencies.

A flexible response

Even if the research situation in developing countries is not known in detail two points are certain: first that the situation is undergoing considerable change; and second, that the limited research capability in most countries reduces their ability to absorb foreign research funds. Such conditions argue for a funding policy which is sufficiently flexible to respond to changing needs and suggests that IDRC will not be overwhelmed by requests for funds, at least in the initial phase of an expanded energy programme. These is therefore no great advantage to be gained from a predetermined and rigidly enforced demarcation of research topics that will be considered for IDRC support.

agencies does provide a clear indication of the general direction and content that such an expanded programme might initially take.

Although a consensus is emerging about the general characteristics of the energy problems facing Third World countries, there is still very little basis for agreeing about what action should be taken in specific locations. Research is therefore a necessary component (often a relatively low cost component) of any course of action. But despite the lack of available resources and the high cost of error, inadequate attention has yet been given by donors or developing countries to the formulation of a strategy for the generation and allocation of the resources available for research. Little is known of the size and distribution of the current research effort; duplication of the efforts of both researchers and aid agencies appears common; Energy Research projects appear isolated from the problems of the people they are meant to assist and from the processes of planning, production and implementation; Third World researchers are often isolated from the stock of existing knowledge and this in turn leads to poor proposals and inadequate research results; much of the existing research focusses on technical issues often to the exclusion of the related social and economic aspects; the rigorous comparison of energy conversion options, carried out under genuine operating conditions and from the technical, economic and social perspectives, is rare.

In this context five general principles appear important in guiding IDRC's support for energy research:

'Consumer Sovereignty'

With most other doners likely to fund energy-related activities in the Third World, it will be important for IDRC to focus on those types of activities which have historically distinguished it from the other donors. This implies assisting Third World countries to determine which issues are most important to them and then funding nationals of these countries to formulate and carry out the necessary research. Other agencies can also take this approach, but, as suggested earlier, the general impression is that the pressure to respond quickly leads most donors to rely predominantly on the skills of expartriates. IDRC is well suited to this independent role for, unlike other bilateral aid programmes, it is not associated with the narrow foreign policy objectives of a particular government nor is it linked to the promotion of particular goods and services from industrialised countries. This independence is particularly important in the energy sector where impartial information is scarce and developing-country governments are increasingly subjected to the conflicting claims of expatriate experts and commercial interests.

Building the capacity to choose

IDRC's style of operation suggests that each programme should focus on those parts of the research agenda which developing countries do best. The earlier discussion suggests that their'comparative advantage' is likely to lie in that research which increases developing countries' capacity to identify problems and make choices between alternatives. This implies that the focus of the IDRC approach should not be to identify particular types of hardware which show promise; rather, it should be to enable countries to make these choices themselves by enabling them to establish what is known,

ii) to test and evaluate the various options currently available;

iii) to adapt the technology to local requirements;

iv) to develop productive capacity for these technologies with their boundaries, or bargain with foreign suppliers;

v) to build the necessary capacity to transfer the technology to users.

Priorities such as these find wide spread support from reports such as UNDP 1979, Weiss 1980, UNERG Research 1981 para. 52.

A second conclusion is that, in spite of the concentration of research resources in developed countries, certain research tasks are best done in the developing countries themselves. Developing countries have a 'comparative advantage' in that research which is intimately related to each country's unique endowment of physical, geographic, social, economic and political characteristics. This is the case with research aimed at the testing, adaptation, and diffusion of technology in the context of local conditions and requirements. It is also a characteristic of research essential to the exercise of political and economic control such as the identification of needs, the definition of priorities, the formulation of policy and all forms of bargaining. A third category of research for which developing countries have a comparative advantage are those where they are the main beneficiaries of the technology and where research is not carried out by developed countries.

The converse of these arguments would suggest that governments of developed countries (and international research centres dominated by expatriates)would most usefully serve the interests of developing countries by focussing their research efforts on areas which:

a) involve very large amounts of money and other resources;

b) where the results are likely to be applicable to a wide range of conditions within developing countries;

c) where international commercial concerns are uninterested in applying their research resources because of their inability to obtain monopoly profits to ensure a return on their investment;

d) where basic scientific principles need to be established or where standard research or evaluation procedures need further development;

e) where use can be made of existing sophisticated equipment or highly skilled personnel. Such research is likely to be concentrated at the more basic end of the applied/basic research spectrum; it might involve the compilation, analysis, and dissemination of existing sources of information; and it might incorporate the role of "honest broker" in the process of bargaining over technology.

Guidelines for IDRC's Support for Energy Research

It is not the purpose of this document to consider the institutional changes that would be required to enable the Centre to expand its assistance to energy research. But the review of issues and the survey of the fragments of information on energy the activities of researchers, governments and aid

alcohol programme of Brazil, the small-scale methane technology of India or China, or some aspects of the wood fuel problem in many countries.

ii) to maintain a good technical competence in anticipation of possible future needs. This is appropriate for options which are not of the highest priority but where changes in energy futures or developments by others may make it desirable for the country to enter into the R and D process with a significant level of funding in the future. For some countries, an example of this might be the film processes for producing photovoltaic cells.

iii) to rely on foreign commercial or government interests where these have programmes likely to satisfy the country's requirements. This strategy might be most appropriate for those options where (a) local demand would be insufficient to justify a national research and development programme; (b) where these foreign interests have such well established research capability that national programmes are unlikely to be able to compete; (c) or where the technical superiority of foreign facilities is likely to overtake national programmes. For many countries, this would be the case for large-scale electricity generating plant.

iv) to acquire and maintain the status of an informed buyer. This would be appropriate where (a) there is a need to establish the local resource potentials before committing funds to a more substantial R and D effort, or (b) where the technology is well established outside the country and is likely to be better or cheaper than the local product.

v) to await developments elsewhere. This would be appropriate for technologies which do not currently meet local needs, but might have relevance in the long term, or if a substantial breakthrough occurred.
(This scheme is adapted from U.K. Department of Energy 1976).

In choosing between these research options, developing countries do so in the world context described earlier:

- that energy research resources in developing countries are generally limited (though less so in the newly industrialising countries, the so-called "NICs");

- that bulk of the world's R and D resources is concentrated in developed countries (over 95% is a commonly quoted figure);

- that the energy problems of many parts of the Third World (particularly in rural areas) are significantly different from those facing industrialized nations;

- that, though possibly more open to question than the previous points, the principles underlying the technical options likely to be applied in energy sectors of the Third World are already well known.

Two important conclusions follow from this. First, that the major energy related research tasks facing most developing countries will be:

First, any allocation of research resources has to be firmly based on a knowledge of the energy situation facing each particular country and the most likely range of future conditions. This future perspective is particularly important given the speed with which circumstances can change within an economy and the relatively long time it takes much research to result in widespread technological innovation. At a trivial level, there is little point in researching on geothermal energy if the local geological structures are unpromising; but more fundamentally there may also be little value in researching activities which are likely to affect few people. An essential component of this view of energy prospects is an understanding of the requirements and capabilities of specific users of energy. It is conventional in much of the literature to consider the various types of 'end use' for energy and then attempt to match these against the particular characteristics of the energy conversion technology. For instance, liquid fuels are particularly suited to end uses which involve mobile engines, while energy from windmills is particularly suited to end uses such as water pumping for which hourly variations in energy supply are not critical (see, for instance, UNERG, 1981, Annex to Chapter II; or Government of Canada, 1979, Table 2.3). But it is also important to understand user needs at the more detailed level associated with the social and economic requirements of particular social groups and to determine the social value of meeting such needs. Perhaps, most important and often neglected in this respect is recognising the limited purchasing power of the potential users of energy-related technology; but it also is necessary to consider social and cultural requirements. Failure of energy programmes, particularly those in rural areas of the Third World, is attributed to an inadequate understanding of such user needs (for example, see Weiss, 1980, para. 3.28 on solar cookers, Shaller 1979, on woodstoves, or Moulik, 1978, on biogas plants).

Understanding current and future energy situations also implies a knowledge of the availability of energy reserves. As already suggested, this information is not known for many developing countries; this is particularly so in relation to the current and potential production of fuels from the biomass, but it is also the case in relation to mineral deposits and hydro sites, (eg UNDP 1979). An insight into the basis of many of these resource estimates and the uncertainty which surrounds them is provided for India by Desai (1980); other examples are given in Beltran 1981 and Fonseca 1981.

A second element in the formulation of any energy research policy involves a preliminary identification of the possible options available to meet future needs and the research necessary to bring these options into use. Against the background of energy requirements, user needs and resource endowment, a number of options can be identified which offer the possibility of making a significant contribution to a range of likely energy futures. These options will involve both technical and non-technical components and will include a range of policies for the management of energy demand and the means by which technical solutions might be implemented. For each of these options, one of five possible research strategies is possible:

i) to take a national lead in order to provide the country with a firm control over the technical orientation and time scale of the research programme. This might be most appropriate for options that (a) seem essential to the country on most views of the future; (b) are currently neglected by the research efforts of other groups; (c) where existing knowledge is lacking. Examples of this option might be the fuel

Isolated pieces of research on specific smallscale technologies are also fairly widespread. Particular emphasis appears to be being given to methane production, (East Africa) solar energy (primarily in Franco-phone countries in association with French and American aid programmes), fuel wood and wind energy.

A Research Strategy

There may be complete agreement that research forms a key component of the response to the changing energy position; but agreement is less easy to establish about the scale of the research that is necessary and the activities which require particular emphasis. A number of papers and reports have been produced in recent years which indicate research priorities. But most of these studies restrict their purview to new and renewable sources, and often are formulated in a vacuum devoid of financial constraints and a knowledge of existing research or capabilities. When necessary these studies will be drawn upon in what follows. But before getting into the details a number of preliminary remarks are appropriate.

It is clearly not possible (or sensible) for each country to adequately research every problem related to the energy sector. The choice of what should be researched could be left to the personal preferences of the individual researchers, and this might be justified with reference to academic freedom. Researchers' preferences are reported to be dominant in many countries' energy R and D activity (UNDP 1980 para. 112, UNERG LA 1981 para. 13). It has to be agreed that much research effort falters because planners (even if they are also eminent scientists) cannot get researchers to do what they do not want to do. But three arguments suggest that control through a research strategy of some kind is required:

i) most research funds in developing countries are supplied or controlled by government (usually a much higher percentage than in western industrialised countries which have a large private research sector);

ii) the international scientific community is dominated by people in industrialised countries whose values, reward systems and research priorities do not necessarily coincide with the requirements of non-industrialised societies (this phenomenon has been widely reported (see, for instance, Herrera in Cooper, 1973, and Reddy, 1979);

iii) although unproductive research activities are an inevitable part of any research effort, it is possible to discriminate between research proposals in terms of their likely value to society.

Any research strategy must strike a balance between requirements, resources, capabilities, and the likely activities of others. The variation in these elements between countries suggests that each country will have to develop its own strategy and any generalisation, particularly about research on particular devices, is likely to be both wrong and misleading. However, a number of general principles have been found useful in generating research strategies.

suggest a number of specified areas that require further research. In particular it suggests that research in coal mining should be re-orientated from research to conserve coal to research related to the massive expansion of coal mining envisaged in the plan; it is also argued that the current annual level of R and D in the power sector (200 million rupees) is disproportionately low considering the size of investment in the sector; much of the current R and D in the power sector is said to involve routine quality control and testing rather than genuinely innovative research. In relation to alternative sources of energy, co-ordinated programmes have been developed in the fields of solar and biomass energy, but the issue now appears to be one of moving from the laboratory to commercialisation. The report notes that the severe problem of popularising the application of the results of all energy R and D programmes when "only a few progammes will lead to direct monetary savings and profits in the near term" (p.386).

Other sources describe over 140 research projects in India on solar-thermal conversion and photovoltaic processes (Tata 1978) and provide progress reports on the 42 public and private institutions undertaking renewable energy research (Tata 1980). Little information is available on expenditure on R and D. The only pattern to emerge from the various listings of projects is that although a great deal of advanced research is being undertaken, there is a marked absence of market surveys, studies of the economic viability of energy technology and social impact studies; however this lack may be due to inadequate sources of information rather than to a real absence of research. India has perhaps the longest history of undertaking rural energy surveys which emphasise fuel wood use.

The research activities of the Philippine Ministry of Energy in the new and renewable energy sector are made available through an annual progress report. Approximately $2.5 million US has been spent on non-conventional energy Research and Development between 1977 and 1980. Eighteen projects have been completed and a further 50 are now underway. Principle achievements are said to be the development and demonstration of producer gas engines using agricultural waste to run 45 kw irrigations systems and wood fired electricity generation plants (the first is rated at 500 kw and plans for another at 2-5 MW). In future greater emphasis will be placed on the delivery and dissemination of technology rather than being limited to technology development. In addition to largely technical research recently approved projects include "social investment analysis of energy R and D under Philippine conditions" and energy demand surveys. The 1980 programme is expected to spend $1.25 million US of local funds in addition to an unspecified amount of foreign support.

Other Asian countries compile lists of energy research projects, but they tend to concentrate solely on so-called new and renewable sources of energy. For instance the National Research Council of Thailand lists (in Thai) 96 research projects on new sources of energy but only two of these are said not to be confined to hardware development.

Information on African energy research efforts could not be obtained although annecdotal evidence and requests to IDRC suggests some research is being undertaken in many countries. For instance attempts to determine rural energy requirements are known to have been undertaken (or are in progress) in Egypt, Kenya, Tanzania, Nigeria and Sierra Leone.

relevant research; this has been achieved in the first instance by commissioning four studies on various aspects of energy policy options facing Latin America, including the oil refining situation, and the prospects for non-conventional sources of energy. Further efforts have been directed towards the production of several methodological manuals to provide assistance to those people undertaking research in the region and to provide a more standard approach to information gathering.

In very broad terms the OLADE studies conclude that there is a very pressing need for research to establish conventional and non-conventional energy reserves of the region, particularly in respect of hydro potential and the researves of uranium and coal. Much of the work that has already been done is limited by the lack of common research standards and definitions. Research capacity is currently not available to adequately evaluate non-conventional sources of energy; the only significant attempt to build up the required research infrastructure in the region is that associated with the Brazilian fuel alcohol programme. The creation of research capacity is constrained more by finance, equipment, and bibliographical material than by lack of skilled manpower. Although OLADE is fully conscious of the importance of research, and its reports have outlined the most pressing tasks for a series of new research centres, it has not yet established a major research programme for the immediate future nor does it count on a sizable increase in funds to support its own research efforts.

The Brazilian alcohol programme has been at the centre of Latin American, if not world, attention for it provides the case of a developing country becoming a world leader in a new energy technology (China and India might also be considered in this category in connection with small scale methane production). $ 900 million US had been invested in the programme by 1979; production was 2.6 million cubic metres in 1978/9,with an anticipated production of 4 million cubic metres in 1979/80 (Brazil, no date). This programme has been associated with a considerable research effort co-ordinated by the ministry of Industry and Commerce and includes research on sugar cane, ethanol production and the modification of automobile engines. However, no statistics on this R and D expenditure have been found. Related research has been conducted both inside and outside Brazil on the possibly detrimental effects of the programme on the welfare of the mass of Brazilian people (see Brazil 1979,FONSECA 1981 and World Bank 1980).

A survey of research activities in Central America (Chacon 1980) reviewed by Beltran (1981) adds support to the view that much research relating to new energy sources is the effort of individuals and that it is only recently that energy planning commissions have been set up in all but one of the countries to co-ordinate activities. The lack of co-ordination is blamed for the erratic nature and duplication of external assistance to the energy sector. Here too most of the research has been confined to the narrowly technical issues of the technology rather than its economic and social viability and to the factors associated with its diffusion; the report describes many researchers as being out of touch with the needs of the potential users of the technology, and this has encouraged the indiscriminate importation of energy technologies. The report identifies seventy four individual projects: 19 solar; 3 wind; 29 Biomass; 11 small hydro and 12 other.

In Asia the most detailed information on energy research activity comes from India. The Government of India's Working Group on Energy Policy (India 1979) devotes a whole chapter to Research and Development policy in the energy sector. Although not a complete review of activities, it does

survey of its Resident Representatives in 102 developing countries UNDP, 1980). The survey indicated that in the spring and summer of 1979 some form of energy research was being undertaken in two-thirds of the countries surveyed, but there was no evidence that this research was part of on on-going process of energy planning and action. They found that only 57 of the countries had undertaken assessments of their non-conventional energy resources, and 33 of these had looked at only one resource; furthermore, "in most cases the assessments were performed by international organisations or bilateral donor countries" rather than by local researchers (Vol. I, paras. 104 and following). The report notes that of the 64 projects that they could identify in developing countries that were connected with non-conventional energy the largest group (20) was for biogas research ("including alcohol fuels"), with 16 for solar, 10 for wind, 7 for geothermal, 6 for woodlots, 5 for small hydro and 10 others. However, it is clear from the other material that this is only a small proportion of the projects that were being undertaken at the time (see also Chacon, 1980).

The lack of research capability is noted by a number of sources (e.g. UNERG Research, 1981) but the series of reports by Dosik and Weiss (1980 and 1981) suggests that this is not universal within the Third World. They stress that although local research capability is vital to the utilisation of new energy technologies other aspects of local technological capacity are of equal importance: namely, the capability to plan, to manufacture and to distribute energy systems. Of the 19 un-named countries they examined, a few had the highest level of institutions, technical skills, expertise in "social analysis" and policy commitment. One such country has successfully produced and diffused a number of energy systems "thoughout its rural areas"; another (presumably Brazil) has become a world leader in alcohol fuels. A second group of countries has the policy commitment and has made a start in developing a consistent programme but lacks capability in one or more of the main tasks (technical R & D, social and economic analysis, surveys and planning, manufacture, implementation). It is the third group which presents the major problem in that their commitment or capabilities are so limited as to make it difficult for them to absorb foreign assistance. Those research capabilities that they do have are limited by their isolation from production and potential users. In terms of the donors' assistance to building the necessary capabilities in developing countries they believe that "not much attention has been given so far to the analysis of end-use needs, the development of local capability to undertake research on the technological, social and economic impact of renewable energy resources, or to the planning for the widespread utilisation of renewable technologies. The creation of local institutions and mechanisms for marketing and commercialisation for renewable energy technologies has also been neglected. Specific projects have frequently been regarded as ends in themselves rather than a means for securing - through extensive testing, evaluation and adaptation - the widespread use of the technologies with the country" (1981, p. 5).

A more detailed picture of energy research activities in developing countries emerges from those few preliminary reviews which have been undertaken and from a number of research registers; but the picture they provide is very incomplete and the data are of variable quality. Among these sources is the brief overview of Latin American research activities which was prepared under difficult circumstances by IDRC's Latin American Office (Beltran and others, 1981). This report outlines the formation by the Latin American and Caribbean governments of the Organizacion Latinoamericana de Energia (OLADE) in 1973. One of the functions of the organisation is to encourage

A third impression of foreign aid to energy research is that much of it is utilised in developed countries or is under the direct control of expatriates in developing countries. Bartlem and Hoffmann's study (1980) implies that the only donor which explicitly provides research funding to nationals of Third World countries as a matter of priority is the European Development Fund (p. 100). Research funding is explicitly described as being likely to take place largely in the donor country (or to be under the control and guidance of expatriates in recipient countries) in the cases of the UNDP (p. 114) USAID (p.81), Holland (p. 64), and Germany (p. 34). For most other countries, the position is not recorded (e.g. SAREC, p. 11). The impression that much of the relevant research on New and Renewable Sources of Energy has been carried out in developed countries is also noted by the ad hoc group on research for the UN Conference on New and Renewable Sources of Energy (UNERG Research, 1981) paras. 5 and 48, and by Weiss and Dosik of the World Bank (1980, p. 11) and UNDP, 1980, Vol. I, para. 11.

A final impression is that as the allocation of aid funds for energy research is not known, there is no co-ordination of donor efforts and research is largely ad hoc. This has resulted in a great variability in the quality of the research (so that the current position has been characterised as one in which there is a great deal of information but very little knowledge!) and the high probability that much of the research that has been undertaken being of limited relevance to the energy needs of developing countries. Much research appears not to be based on an understanding of what is already known; this has been particularly acute in the research on improved wood stoves (see, for instance, Agarwal, 1980) and the small scale production of methane (see Pyle in Barnett and others, 1978).

Agencies such as the Rockefeller Foundation and the Ford Foundation have previously provided a catalytic role in the energy sector. For example, the Ford Foundation provided funds for one of the first reviews of the issues surrounding energy in agriculture by Makhijani and Poole (1975); the Rockefeller Foundation provided an innovative small grants programme to energy research. But neither agency currently plans any significant programme of assistance to energy research in the future. Other agencies have provided funds for authoritative reviews of energy subjects; for example, World Bank's Study on Energy from Alcohol, the UNDP and World Bank's Study currently in progress on photovoltaic water pumping systems and NAS's review of fuelwood tree species. ILO currently provides a few grants of up to $20,000 each to support research on issues relating to the social implications of alternative energy policy in developing countries and gives preference to researchers from the Third World.

Current Research Efforts of The Developing Countries

It is generally acknowledge that there has been a considerable expansion during the 1970's in the energy research of developing countries despite an acute lack of trained researchers. But so far there has been little "research on research" which might provide an overall picture of research expenditures and the direction that the research is taking. Perhaps inevitably with such a recent upsurge in interest, much of the research that is taking place is in the form of unrelated projects, with much duplication and a tendency to research issues that are already well known within the scientific literature. This view was very much confirmed by the UNDP's

The report states that the level of non-government energy research is not known but for ten countries for which data are reported, they are said to be funding 40% as much as all IEA governments, (IEA, 1980, p.27).

Government expenditure on energy research, development and demonstration represents the highest proportion of GDP in the US (1.6%), with the UK at fourth place with 0.99% and Canada at tenth with 0.62% (but this excludes expenditure by the Provinces). No attempt is made by the IEA to suggest how much, if any, of this research is directly relevant to developing countries.

Despite the lack of firm evidence of the energy research funding activities of the aid agencies, certain general impressions can be formed on the basis of the existing literature and interviews with aid administrators. Ironically, much of what is known relates to research on new and renewable sources of energy rather than more conventional energy sources. This is perhaps largely because of the current flurry of activity in preparation for the UN Conference, but it may also reflect the fact that much of the conventional energy technologies are well established and possibilities for Third World technical research are limited. This would certainly appear to be the case with large scale hydro electric generation technology which is largely monopolised by developed country suppliers; but it should not be concluded that other relevant research is not being undertaken in relation to conventional energy technology - just that there is little published information about it. One area in which there is increased activity and which might be included in a wide definition of research, is the programme of the World Bank (and more recently CIDA through PetroCanada) to accelerate the exploration for oil fields that are unable to attract sufficient private finance. The World Bank expanded its assistance to oil exploration and production in 1979 under its "Accelerated Program"; of the 18 petroleum projects funded so far 9 have been for predevelopment which includes a significant research element, and 9 for production; a total of $1,350 million US will be expended on this programme in Financial years 1979-81.

One impression of aid to more narrowly defined energy research is that there has been a concentration on the 'hardware' rather than research into energy requirements and the social and economic viability of the technology. The relative absence of the latter form of research has been noted by Bartlem and Hoffmann, Weiss and Dosik and UNERG. The main area of social science research appears to have been associated with energy planning, but this has largely been in the form of technical assistance. Ashworth, for instance, describes the US Department of Energy's recent Energy Sector review of Egypt as involving 40 Americans (Ashworth, 1979, p. 7); other studies have been undertaken or are planned under this programme in Peru, Argentina, Portugal and South Korea.

A second impression is that there has been an expansion of support for research related to fuel wood; this is associated with the apparently major change of focus that has occurred during the 1970's in the orientation of forestry programmes away from the production of commercial timber alone towards a wider perspective of wood's uses which includes its use as a fuel. Such a shift in emphasis has been noted in the programmes of the World Bank and the FAO and has led to programmes for 'social and community' forestry and 'agro' forestry (see, for instance, Spears, 1981). It appears likely that the UN Energy Conference will give added emphasis to the importance of aid to fuelwood programmes and associated research is predicted.

Hoffmann mentioned earlier, provides almost no firm evidence on research funding.

This lack of data on research activity, although prevalent in many of the fields supported by IDRC, is particularly severe in the energy sector and was acknowledged as forming a significant constraint to the expansion of their own programmes by many of the donors interviews (see Annex I). Part of the problem is undoubtedly the novelty of interest in the field and its rapid expansion in the 1970's; but there are also problems of definition. IDRC's charter defines research very much more widely than other agencies.[1] For instance, many of the activities described in the review of the energy activities of the UN system (UN ECOSOC, 1979) could be classified as research under IDRC's definition; they include studies of "prospects and trends" for each energy source, studies on "exploration and production", studies on aspects of transport, utilisation, conservation and management as well as research itself (although, of course, many UN activities are distinguished from those of IDRC by their predominant use of expatriates). Furthermore, research activities of the donor agencies often form indistinguishable parts of larger capital aid or technical assistance projects. The most extreme example of this is perhaps the recent alcohol fuel project agreed between the World Bank and the Government of Brazil under which $150m US is allocated to "technology development" out of a total project of $3,000m (the World Bank's contribution to the whole project is of the order of $130m); much of this activity will be research and development but it will not be classified as such in the Bank's statistics.

The interpretation of those data which do exist is made more difficult because, as with all statistics on R & D, the measurement of research effort is anyway fraught with difficulty. Expenditures in cash terms are only a partial indicator of priorities as research costs vary greatly between countries and the value of research is often not related to its cost. The International Energy Agency, which compiles energy research expenditure data for OECD countries, laments that "no generally recognised indicator for the measurement of relative performance of countries has been found; i.e., a quantitative relationship which might provide the basis for assessing the adequacy of.....individual efforts", (IEA, 1980, p. 14).

The only comprehensive evidence about energy research funding is provided for developed (OECD) countries by the International Energy Agency. Their report for 1979 shows that out of the total government-funded research, development and demonstration, the proportion directed to the nuclear industry has fallen from 77% of the total expenditure in 1974 to 55% in 1979; that the proportion allocated to conservation has risen from 2% to 6%; and that research on solar, wind, ocean, biomass, and geothermal has risen from 1% in 1974 to 12% in 1979 (IEA, 1980, p. 20). This is in a budget that totalled over $7,000 million in 1979 (a 130% increase in real terms over the 1974 figure), of which the US accounted for 54% of the total (IEA, 1980, p.14).

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[1] The Charter of IDRC states that "research includes any scientific or technical inquiry or experimentation that is instituted or carried out to discover new knowledge or new means of applying existing knowledge to the solution of economic and social problems; 'science' includes the natural and social sciences" (para. 2). Furthermore, it is within the powers of IDRC to "initiate and carry out research and technical development, including the establishment and operation of a pilot plant or project, to the point where the appropriate results of such research can be applied" (para. 4, subsection 2b). Canada, 1970).

there has never been within the (U.N.) system any machinery, formal or ad hoc, for intersecretariat consultations. This lack of a mechanism might be felt not so much in relation to the elimination of overlaps and duplications, but rather from the point of view of establishing a concerted general approach by the system" (para. 135). Although the listing does not provide enough information by which the precise nature of each project can be determined, most of the projects appear to be some form of technical assistance. The report provides only an "estimate of the orders of magnitude" of financial allocations but this shows that under the regular programme budget of $16 million for the period 1978-81 the largest allocation went to nuclear power (34%), 18% went to overall energy issues and 16% went to fuelwood and charcoal. In the extra budgetary programme of $90 million, 37% was allocated to fuelwood and charcoal, 13% to nuclear power and 10% to oil and gas (page 37, Add. 1).

It is too soon to anticipate the outcome of the UN's Energy Conference, but at the very least there is likely to be far more co-ordination of the UN's energy activities; suggestions for a new UN energy institution (whether for research, training, or more general aid disbursement) have apparently met with little support, although some additional secretarial function, located within an existing UN institution, may be agreed.

IV. THE QUESTION OF RESEARCH IN DEVELOPING COUNTRIES AND THE IDRC RESPONSE

Current Research Efforts-the aid agencies

Ideally any plan for expanding IDRC's assistance to energy related research should be framed in the context of a reasonable knowledge of what other aid agencies and developing country governments plan to do. It is therefore a significant finding of the current review that no secondary source material exists from which such an overview could be compiled without undertaking extensive primary research. Those reviews which have been undertaken are either entirely silent on the question of research funding or provide only the most general impressions of current activity. For instance, the OECD's attempts to monitor its members' activities in the energy sector (OECD, 1981) was unable to identify a single commitment from either bilateral or multilateral agencies for a category covering research (see Table V) and only one donor (US AID) who had committed funds to the category including feasibility studies and the testing of energy hardware. However the Table shows that 22% of all commitments were "unclassified". Furthermore, the ad hoc group of experts convened to advise the UN Conference on New and Renewable Sources of Energy on Research (UNERG Research, 1981) was severely hampered by the lack of information on the research activities of either donors or developing country governments. Those data which are provided are described as not being comprehensive (para. 4) and are limited to a very narrow range of technologies and countries.[1] The review by Bartlem and

[1] The report provides data on only five developing countries in its table showing government supported research, development and demonstration for renewable energy sources (excluding large scale hydro and geothermal projects) in 1980; these were India, $20m; Saudi Arabia, $15m; Egypt, $6m; Algeria, $1m; and Libya, $2m. The same table shows a figure of $9m for Canada and $1,100m for the US. The source of the data is the Financial Times, London (UNERG Research, 1981, Table I).

A further indication of the future plans of the major donors is provided by a report compiled by Bartlem and Hoffmann. Their original research was in preparation for the IBRD meeting on Assistance to the Energy Sector in Developing Countries (Paris, June 25-26, 1979) and some of their findings were summarised in a draft report to the Rockefeller Foundation dated February, 1980. It is not clear how much their report reflects the views of the donors, but to the extent that reliance can be put on the findings, certain conclusions can be drawn: first, they note the widespread attempt by aid agencies to develop and articulate new policies to meet the energy needs of developing countries since the shocks of the early 1970s. However, as suggested earlier, actual resource allocations still reflect traditional funding patterns which concentrate on large-scale electricity generation and supply.

Bartlem and Hoffmann particularly remark on the inadequacy of aid programmes to develop local capabilities to co-ordinate, plan and implement national energy policy (page 128). They conclude that "developing country personnel trained in renewable energy and energy planning are generally scarce, as is any type of research infrastructure in which such personnel could work; US AID and the World Bank have identified these as priority problems, but no programmes to address them are really underway (page 126). Similar views are to be found in Weiss and Dosik 1980, UNERG, 1981 and the OECD, 1981 .

One feature of a number of bilateral programmes is their explicit policy of promoting their country's exports. While such a link between aid and trade promotion may be a necessary price that aid agencies have to pay to maintain their budgets, it does have the effect of compromising the independence of the advice offered by aid agencies in the minds of recipients. This is particularly relevant in the energy sector where so much of the information available is already unreliable. It is also said to lead to the practice whereby the testing of energy technologies in developing countries by aid agencies under emphasises economic considerations and locates the tests in conditions which exhibit the technology to its best advantage, whether or not such conditions are common (Bartlem and Hoffmann, 1980, pp. 125 and 126). Some countries imply a strong link between their aid and trade in their submissions to the OECD review (1981). Bartlem and Hoffmann specifically note the link in the programmes of the US Department of Energy (page 86), the German research programme of the Bundesministerium für Forschung and Technologie (BMFT) (p.31), France (p.44) and Canada (pp. 12 and 17).

Further descriptions of specific aspects of bilateral aid activities in the energy sector are provided by Ashworth (1979), the Forest Service of the US Department of AGriculture (1980), and Lawand, 1981.

Turning now to the future activities of the UN system much depends on the outcome of the UN Conference on New and Renewable Sources of Energy which will take place in Nairobi in August 1981. However, as part of the preparations for the Conference, the past energy activities of the whole UN system were reviewed for the two year period 1978-79 (UN Committee for Programme and Co-ordination, 1979). Their funding covers the full range of conventional and non-conventional energy sources which were summarised in 83 pages of tables. No overall pattern emerges from these tables and this is to be expected as the report notes that "it should be pointed out that

donor to the energy sector (see Table III). In 1980 the Bank published its plans for funding the energy sector during the five-year period 1981-85. (World Bank, 1980). The anticipated programme is for $13,190 million US with the bulk (57%) being allocated to electric power generation and distribution; a further 30% will be allocated to investments associated with oil and gas; and fuel wood would receive 3.2% and fuel alcohol 1.5% of the funds. The World Bank considered that this programme was somewhat less than the amount required to meet the urgency of the situation and they therefore suggested an alternative 'desirable programme' of $25,000 million. This programme would expand the funds available to each of the areas supported by the current programme but the proportions would be altered by the inclusion of a new expenditure category for 'industrial retro fitting' of devices to increase the efficiency of energy use in industry (see Table IV). It was hoped that the additional funding for the expanded programme would be provided by a new "energy affiliate" of the Bank; however this now looks uncertain with the recent decision of the US Government to defer its decision to support the scheme.

The second largest group of donors are the OECD countries. The energy policies of all these countries have been under review (see, for instance, US AID, 1981; SIDA, 1980) and their activities have been summarised in a recent publication prepared as a contribution to the UN energy conference (OECD, 1981). The document shows that, as was the case with the Bank, the bulk of commitments are for electricity generation and distribution; in 1979 84% of a total DAC bilateral commitment to energy of $1,592 million US was allocated to this type of project (see Table V). Such commitments will dominate actual disbursements for many years to come but the OECD report notes that "several DAC countries have recently launched important programmes and activities in the area of new and renewable sources of energy" (para. 10) "assistance policies towards these objectives aim at strenghtening the scientific and technological capacity of developing countries and their R & D efforts to find technological solutions appropriate to their circumstances. Several DAC countries have also programmes designed to demonstrate new energy technologies in the technical, socio-economic and national context of developing countries in order to test their suitability and acceptance" (para. 11, OECD, 1981).

The OECD document provides eleven pages of description of the planned activities of its members in the field of new and renewable energy technologies. Generalisations from such descriptions may be unreliable as they are not standardised for each country; but insofar as generalisations can be made, it appears that most donors will give greater emphasis to energy than they have in the past. This expansion is explicitly noted for Australia, Belgium, Canada, Germany, Italy, UK and the United States. Large scale electricity generation and distribution is likely to remain a major component of most programmes (particularly mentioned in this respect are Australia, Canada, France, Germany, Japan, Netherlands, Norway, Sweden and the UK); research is mentioned in the programmes of six countries, but as will be discussed in more detail later, much of this research is likely to be carried out in the donor country or in collaboration with expatriate researchers. Afforestation is identified as being important in the programmes of Germany, Sweden, Norway, Switzerland and the United States. Resource evaluation is mentioned in the Canadian programme, while emphasis on other aspects of energy policy formulation and planning are identified in the Swedish, American and EEC programmes. The demonstration of hardware is a significant feature of the German, French and American programmes. The New Zealand programme is dominated by large geothermal projects in Indonesia and the Philippines.

the turn of the century. The OECD, for instance, concludes that "new and renewable sources of energy provide an important challenge, especially for satisfying decentralised energy needs in rural areas, but cannot be expected to make a significant contribution to the energy supply for the next 10-20 years.....while new sources of energy deserve adequate attention, the energy problems of the developing countries are too urgent to rely primarily on solutions with long lead times" (OECD, 1981, p.4 para. 4(e)).

The UN Conference on New and Renewable Sources of Energy ably withstands the pressure to make unsubstantiated claims for the various technologies. The draft programme of action argues that "the development and utilisation of new and renewable sources of energy must be viewed in the context of the overall energy transition. New and renewable sources of energy can make a significant contribution, but their role and potential should not be overstated. In the foreeable future hydrocarbon supplies will continue to play the dominant role in meeting global energy demand, but over time that role must perforce decline relatively.....thus while the short-term potential for new and renewable sources of energy may be limited in the global sense, the longer term potential must be considered as a very dynamic variable that will tend to increase in importance with time and with the refinement, development and application of technologies" (para.17, UNERG Draft Programme of Action, 1981). The Synthesis report further suggests that the current contribution to the world of these sources of energy is of the order of 15% and that this will have to rise to about 25% by the turn of the century -- or a fivefold increase in absolute terms if predicted needs are to be met (UNERG Synthesis Report, Chapter 5, para. 3). They do not suggest that such a five-fold increase in absolute terms will be easily achieved!

III. THE RESPONSE OF THE AID AGENCIES

The major aid agencies face considerable difficulties in restructuring their programmes in the short term to meet new needs; and even though it is nearly ten years since energy became a dominant issue facing developing countries, the aid programmes are only now beginning to publish energy policies which will affect the size and shape of their funding to the sector. Many agencies currently face static or even declining budgets which necessitate new initiatives having to be matched by reductions in other current activities. Furthermore, recipient countries themselves have limited capacities to absorb funds in new areas. Historically, the bulk of energy aid has been allocated to large scale electricity generation and its distribution. Such projects are in many ways ideally suited to large capital aid programmes in that because of their large size the funds are relatively cheap to administer and the technology does not require significant adaptation to local social and economic conditions. If aid agencies are to depart from this traditional form of support in the energy sector, they have to confront problems associated with the identification and administration of larger numbers of smaller investments, and are involved with technologies and local conditions of which they have less experience and expertise.

However, a number of secondary sources have become available in recent years which indicate in general terms the direction that aid agencies are likely to take in future. Historically the World Bank has been the largest

thought to be 1.6 times more coal reserves than oil reserves, 90% of recoverable reserves are ir western developed countries or in centrally planned economies (IBRD, 1980, para. 2.5). Almost all countries have unexploited hydro potential. The World Bank lists 90 developing countries with unexploited hydro potential estimated at 1,200 gW of which 10% is for minihydro plants of less than 1 megawatts (IBRD, 1980, p. 46 and Table 5 of Annex II).

The prospects for nuclear energy are still uncertain in terms of the actual cost of the resulting electricity and the safety of the plants in use. But it is clear that the current commercial plant size of 600 megawatts limits their application to those countries with a sufficiently large grid size. The World Bank predicts that only 15 developing countries will have such a grid (5,000 mW) by the year 1990 (IBRD, 1980, p. 47).

c) Other Sources of Energy

There are a number of other technologies which are thought to have potential for developing countries. Among the small-scale technologies, a number are based on well-known principles, such as windmills, waterwheels, small-scale hydro, and the direct heating of water by the sun. Others which are still largely experimental or for which there is little experience of production include the direct generation of electricity through photo-electric cells, solar ponds (which utilise heat gradients in salty water), and various types of 'heat pump'.

The potential of these technologies is considered to be large by some authorities, and they are thought to be particularly attractive in that they offer the possibility of decentralised energy systems suitable for disbursed rural populations. Further development work is often recommended to reduce their cost, to make them more robust, or to adapt them to local user requirements. However, it is widely acknowledged that there is an almost total lack of physical and economic data from rigorous comparative tests of these technologies under a variety of genuine field conditions (Weiss and Dosik, 1980; Barlem and Hoffman, 1980; UNERG, 1981; US AID 1981; UNDP, 1980).

It is also to be expected that the widespread diffusion of these technologies will be confronted by many of the problems that have constrained the diffusion of such well known technologies as water pumps and the new varieties of wheat and rice and which currently hamper the diffusion of improved wood stoves and household biogas plants.

Among the larger-scale technologies, possibilities already exist for harnessing geothermal energy and energy from tar sands and oil shale. Wave and ocean energy offer other possibilities in the medium to long term. It is also expected that in the medium term ethanol will be economically converted from woody material by microbiological processes and methanol will be produced by gasification and synthesis(but methanol is more toxic than existing liquid fuels - see Kirk & Othman 1970 vol.13 p.394).

Opinion is divided about the general prospects of these new and renewable sources of energy providing substantial additions to primary energy. The World Bank and the OECD DAC suggest the possibilities should be pursued, but they do not see them making a major impact on the total energy supply by

the selection of species particularly suited to the production of fuel wood or species which have multiple uses (such as providing fodder, fruit and the fixation of nitrogen in addition to providing fuel); these are succinctly reviewed by the National Academy of Sciences (1980). But there are generally agreed to be formidable obstacles to maintaining even the current levels of consumption of these commonly used sources of biomass for fuel. The problems are primarily problems of 'software'. At one level, there is the question of obtaining the political will necessary to make available the funds for such schemes; there are problems associated with the current institutional infrastructure which is largely oriented to the production of commercial timber rather than fuel; and there are problems associated with establishing a sufficient degree of community participation and land reform that is now widely recognised to be a necessary component of fuel wood schemes (see Arnold, 1979; World Bank, 1981; US AID, 1980).

Other technologies currently exist which would either enable a greater use to be made of the existing biomass or which might justify the additional production of biomass for fuel. These technologies include the production of methane gas from cellulose (particularly animal dung), 'producer gas' from the partial combustion of carbonaceous material such as wood or straw, methanol through the destructive distillation of wood, and ethanol through the fermentation and distillation of carbohydrate material such as sugar-cane, sugar beet or cassava. These technologies are reviewed extensively (see, for instance, UNERG, 1981; Barnett, Pyle and Subramanian. 1978 on methane; World Bank, 1980 on alcohol). Considerable potential exists for improving these technologies and for making them more suitable to a wider range of circumstances.

b) Conventional Commercial Sources of Energy

Concerns about the immediate and medium-term future are concentrated on oil. In the short term, the World Bank predicts that oil prices are likely to rise in real terms by at least 3% per year throughout the 1980s (IBRD, 1980, para. 1.01). In the longer term, the prospects for oil are conditioned by the fact that current world consumption of oil is now equal to, or even exceeds, the rate at which additional reserves are being found. However, the distribution of oil exploration effort is concentrated in the 'safe' (largely northern) areas controlled by developed countries to the neglect of a number of promising geological structures under the control of developing countries (see North-South Energy Round Table 1980, PIII 1-8). This suboptimal exploration effort has been recognised by a number of agencies who are trying to encourage exploration in these areas by the large corporations or are trying to mobilise consortia of the relevant contractors. The IBRD now finances such work (IBRD, 1980, pp. 68-69) and consulting firms with an orientation to the exploration needs of developing countries have been created (for example, PetroCanada International and Maurice Strong's International Energy Development Corporation).

Within this general picture, the distribution of oil reserves is very uneven within developing countries. The oil supply position facing oil-importing developing countries is one of unreliable supply and rising real prices. For other fossil fuels (coal and gas), the distribution is better than for oil but it is still uneven. For instance, although there are

In developing countries, the useful energy produced by burning wood in an open fire is said to be of the order of less than 12% of the primary energy contained in the wood. Thermal electric generation stations might typically be 25% efficient, with the most efficient modern plants achieving efficiencies nearer 35%.

In the modern industrial sector, improvements are possible at three levels of investment. The first, involving no investment, achieving greater efficiency through the better "housekeeping" practices mentioned earlier; at a second level, through minor adaptation to exisitng plant (including the 'retrofitting' of improved bearings, better insulation, waste heat boilers and so on). Only at the third level, where further improvements in efficiency can only be achieved by the installation of more efficient plant and equipment or through changes to less energy-intensive products, is major investment involved.

In the rural sector, the problems of increasing efficiency appear, at first sight, disarmingly simple. The low level of combustion efficiency generally achieved in the direct burning of fuel wood and crop residues has often led to the automatic conclusion that massive energy savings could be achieved by more efficient stoves. However, it is increasingly recognised that such savings have been difficult to achieve in practice even though large improvements in combustion efficiency can be achieved by improved wood stoves in the laboratory; a doubling of combustion efficiency is commonly mentioned (see, for instance, UNERG Synthesis Report, 1981, para. 48e.) The difficulties stem largely from the variability of rural people's requirements; these range from the different types of cooking tasks, to space heating and to socio-cultural requirements of hearths. There is also no necessary logical connection between increases in stove combustion efficiency and reductions in the amount of fuel actually used; it is quite possible that the users will merely enjoy more useful heat from the same amount of fuel. The literature on the subject of the diffusion of improved wood stoves is still sparse but has recently been reviewed by Agarwal (1980) and a forthcoming study of the U.S. National Academy of Sciences.

Increasing the Supply of Primary Energy

The detailed prospects for increasing the supply of primary energy have still to be determined for most developing countries. However, a number of reports are available which review the situation in global terms. A useful recent summary of current knowledge is provided by the World Bank's report, Energy in Developing Countries (1980, pp. 12-48). Other studies are also available detailing current knowledge of reserves for particular energy sources (e.g. the World Coal Study). Rather than repeat these summaries here, a number of features will be highlighted.

a) Fuel wood and other biomass fuels

The problems of fuel wood and other traditional fuels of rural people are widely considered to be the most pressing fuel problem because of the vast numbers of poor people who rely on them. The technology for increasing the supply of this kind of fuel is known and widely available. Further improvements in productivity are generally agreed to be possible through

In addition to better "housekeeping", conservation can also be achieved by a better match of energy sources to end-use requirements; unnecessarily expensive or 'high quality' energy forms (e.g. high temperature heat or electricity) are often used in applications which could equally utilise energy of a lower quality. A better match can be encouraged through the harmonisation of government policies which determine the price of competing sources of energy, and the taxes and subsidies which affect the demand for energy-using technology. Few countries (whether developed or underdeveloped) are said to have such entirely rational pricing policies and difficult political choices are involved in their implementation. For instance, the price of kerosene is often kept below the costs of its importation in order not to harm the welfare of large numbers of rural people who use it as an illuminant (see World Bank, Table VI-9, August, 1979). However, such a subsidy may well prevent higher prices being charged for diesel which is adulterated by kerosene as soon as a significant price difference occurs. This in turn leads to a greater use of road rather than rail haulage. A further example might be the flat rate tariff for the domestic consumption of natural gas in Bangladesh which is said to encourage the continuous burning of gas in each household to economise on the use of matches. Taxes and subsidies which are primarily set as part of a general revenue policy can also inadvertently encourage the wasteful use of energy. Examples of this might be where subsidised loans are available for tractors but not for draft animal power.

More fundmentally, the demand for energy is strongly influenced by the pattern of economic and social development. In principal at least, developing countries do not have to follow the oil-dependent form of development experienced in the industrialised 'northern' countries. At the most obvious level, private transport is very much more energy-intensive than public transport. The use of oil in socially unproductive private transport by the richer elements of society has direct implications for the use of scarce fuel in the rest of the economy, most pressingly perhaps in agriculture. Similar issues of equity (and efficiency) are involved when scarce resources are allocated to produce fuel alcohol from the biomass to satisfy the fuel needs of urban motorists. At another level, particular agricultural or industrial strategies are more intensive of imported 'non-renewable' energy than others.

For these reasons policies directed at questions of equity and the distribution of income are a necessary element in the determination of the pattern of future energy consumption. They also indicate that there are a range of important policy options available to confront energy problems which do not involve the supply of energy-related hardware.

The Improvement of Energy Conversion Efficiency

The current use of energy, in terms of the way primary energy is converted into "useful" energy, is very much less efficient than it could be. There are, of course, large unavoidable losses involved in converting and distributing primary energy, such as coal or crude oil, into 'delivered' energy (such as oil products or solid fuels), and yet more losses in converting this energy into "useful" energy by means of appliances, machines and processes. Typically, in Britain, there are 30% losses between primary and delivered energy and a further 30% loss in utilisation. There is, however, room for some improvement in these efficiencies in all countries.

Second, the international trade in technology takes place in a context of international competition and in a context of intense bargaining. This bargaining process is often on very unequal terms when developing countries are involved, in that the resources available to the international corporations can often greatly exceed the resources available to even the largest Third World country. One aspect of this imbalance involves the current distribution of the world's research and development resources. Over 95% of the world's research and development takes place in developed countries. This has the result that the bulk of technical advances in energy-related technology will emanate from developed countries; and this in turn has powerful effects in determining which particular technologies will be developed and the way in which they will be developed. Technologies are changed primarily to meet the requirements of the countries in which they are developed. In the energy sector, the requirements of developed countries are often unlike those found in developing countries. (UNERG Synthesis 1981, Weiss and Dosik, 1980; Barnett 1981).

The pressures of international competition tend to produce only that technical change that will provide the innovator with a sufficient degree of monopoly to generate an adequate return to cover the costs of research and development. Such monopoly elements reduce the ability of developing countries to properly absorb the technology they import. But they also lead to greater levels of funds being allocated to technologies which are difficult to copy, such as photovoltaic cells, than to more simple and replicable processes, such as those involved in the production of methane gas from cow dung.

These contextual factors are not described to suggest that nothing can be done by developing countries; but rather that Third World responses to their energy situations will have to confront these problems and possibilities.

The Management of Energy Demand

Of the three possible options in dealing with energy problems, the management of energy demand offers the best prospects for immediate and cost-effective results. This is particularly so in those sectors of industry and transport which are currently large users of commercial sources of energy. Energy conservation initially requires little investment expenditure and is based on better "housekeeping" which cuts down the unnecessary or inappropriate uses of energy. The World Bank estimates that in general a 15% cut in developing countries' commercial energy use could be achieved by 1990 without reducing economic growth by such a programme of demand management, equivalent to 4½ million barrels of oil per day (IBRD, 1980, pp. 64-65). However, it is notable in this respect that the survey of UNDP resident representatives mentioned earlier reported that "generally, energy conservation is not a significant concern of the countries represented in the survey" (para. 90) and where it did take place it was directed only at commercial sources of energy particularly in the form of price rises for "motor vehicle fuel" (paras. 91-2, UNDP, 1980).

II. THE GENERAL RESPONSE

Many of the immediate responses to these problems have been automatic, unplanned and have resulted in a number of harmful consequences: as oil prices rose, oil consumption was generally reduced but particularly by those that could not afford the higher prices regardless of their need. As fuel wood became more scarce, people walked farther to collect their requirements, they switched to burning dung which would be more productively used as fertilizer, and they cooked less frequently. However, for some people the effects of oil price rises were ameliorated by the recycling of oil revenues from the oil- exporting countries and from the increased opportunities for migrant workers in the Gulf States, and from a fortunate sequence of monsoons (see, for instance, Desai, 1980).

It is arguable whether the adjustment of economic systems to changes in the prices of the 'factors of production' (such as those resulting from the change in oil prices) is entirely adequate and automatic even in developed market economies. But such automatic adjustment is unlikely to be adequate in developing countries where markets are undeveloped (indeed, where a significant proportion of transactions do not even enter the market) and where the technical capabilities to make the necessary adjustments do not exist. For instance, the substitution of coal for oil in the firing of thermal electric power stations not only requires the necessary capital investment but it also requires the technical capacity to plan, design and implement the necessary changes.

Insight into the way that developing country governments have responded institutionally to the changing energy situation is provided by the UNDP's survey of its Resident Representatives in 103 developing countries. The survey which was carried out in the spring and summer of 1979 shows that over half the countries surveyed had established cabinet level ministries or departments of energy (para. 24) and that this was a recent phenomenon (para. 87). The main emphasis in the conventional energy sector was on developments in petroleum (32% of countries) and large scale hydroelectricity (19%); while in the non-conventional energy sector, of the 106 projects identified 64 were for research, 32 for demonstration and 10 for commercialisation (para. 110, UNDP, 1980). But the capacity to undertake planned action has been widely recognised as being inadequate (see, for instance, the Synthesis Report of the UN Conference on New and Renewable Sources of Energy, paragraph 57, henceforth referred to as UNERG Synthesis, 1981).

In principle, there are three types of response to the changing energy situation: to manage the consumption of energy; to increase the efficiency with which existing sources of energy are converted into useful work or heat; and to increase the supply of primary energy. But before discussing each of these possibilities, two more general points need to be made. First, the amelioration of current energy problems takes place in the context of a world that is already out of balance in a number of respects in addition to the imbalances associated with energy. Much depends on the actions of the developed countries in determining the characteristics of this context. The developed countries' policies for controlling their own energy use and resource development will determine what is available to countries that are less able to make their needs felt in the marketplace. Developed-country trade policy likewise determines the room for manoeuvre open to the Third World by affecting their foreign exchange reserves.

gas production plants break down and are too costly (see, for India, Moulik, Srivastava and Shingi, 1978), rural electrification can only be afforded by a small proportion of the community (see Harriss, 1977). The introduction of more efficient energy conversion devices which substitute for human labour (such as solar water pumping systems) may have an adverse effect on wage labour. The use of a particular commodity (such as cow dung in methane gas plants) can deprive traditional users of its value (see, for instance, Prasad, Prasad and Reddy, 1974). The introduction of energy-related technology which involves the use of cash income tends to compare very unfavourably in the estimation of rural people who can still obtain non-monetized sources of fuel, albeit at considerably personal cost in terms of their labour time.

The complexity of rural energy systems also implies that policy responses can be formulated at a number of different levels, only some of which are likely to be effective. To take one example, scarcity of wood for fuel may be caused by commercial timber exploitation or the removal of forests to make way for food production. Traditionally acceptable levels of fuel wood cutting may become unsustainable following the increase in cattle ownership and consequent overgrazing. But even where the cutting of wood for fuel by subsistence peasants is identified as the major cause of deforestation, it may be the last desperate act of a people who are denied access to other means of livelihood. Responses are only likely to be effective if they are based on a clear understanding of such causal relationships.

Within these gross aggregates of rural and urban energy use there is, of course, considerable variation between countries. Such variation includes differences between the oil-producing and oil-importing countries, between those countries with major fuel wood shortages and those with no such problem, between countries with the funds and technical capacity to respond to the changing energy picture and those with more limited capacity. One such classification of countries is shown in Table II.

While the problems outlined in this brief review may be no more important than the many other problems of under-development, energy problems are certainly very severe and affect a very large number of the world's population; they may also cause irreversible damage to the environment. But they may be distinguished from these other problems because of their newness (or at least the recent recognition of their importance). This newness means that the resources and facilities to respond to energy problems are even more underdeveloped than in other sectors.

As with the industrial and transport sectors, it is difficult to envisage rural development in the short- and medium-term future which does not involve a greater use of commercial energy, primarily oil. In the same way that national oil problems might be seen in the short term as a problem of the international distribution of the resource, so in the rural sector the problem is also one of the distribution of the resource between urban and rural uses and between uses of different social value: between the production of food and the conspicuous consumption of private cars.

However, the most pressing problem facing rural populations predates the oil problems of the late 1970s and affects more than half of the world's population. Although data about rural energy use and supply are scarce and unreliable (such sources still do not appear in the common sources of energy consumption statistics), it is generally agreed that inanimate energy needs in the rural sector are overwhelmingly for domestic purposes such as cooking. It is further generally agreed that current energy consumption is met almost exclusively from renewable sources of the biomass, such as fuel wood, crop residues, and animal dung. Such sources are predominantly not exchanged for money and are collected directly by the user (usually women and children).

The amount of these biomass fuels which can be sustained by regrowth is generally accepted to be considerably less than current consumption in many parts of the world and certainly less than likely future consumption in a much wider area. Reliable estimates of these balances are not available for many areas of the Third World. But the FAO has recently completed an impressionistic survey which suggests that more than 100 million people currently live in situations where they are unable to obtain sufficient fuel wood to provide even their minimum needs; a further 1,000 million are affected by less but identifiable shortages (FAO, Dec. 1980).

The energy problems of rural areas are in many ways different from the problems of urban industrial areas. This is primarily due to the non-commercialised nature of rural energy sources and the significant proportion of the energy supplied by human and animal muscle power. Indeed, the differences between urban industrial sectors and rural energy activities are often greater than the differences between the energy problems of the industrial sectors of developed and developing countries. Following recent research, initial naivety in the published literature about the simplicity of rural energy systems is currently giving way to an appreciation of their variety and complexity (studies by Briscoe, 1979, and M.N. Islam, 1980, both in Bangladesh, are typical of this recent work).

The production, collection and use of energy in rural areas is inextricably linked to the other production and cultural systems which characterise these areas. A number of important consequences follows from this. Energy requirements vary considerably between geographical areas and between different social groups within these areas. The viability of particular energy conversion devices crucially depend on the precise configuration of factors at each location. The introduction of new energy conversion devices are currently confronted with many of the difficulties experienced in the other (better documented) attempts at rural technical change, such as in the fields of agriculture and health. Improved woodstoves are commonly found not to meet user requirements (see, for instance, Shaller, 1979; Hoskins, 1979; Agarwal, 1980; Roy and others, 1969), small methane

For some countries, the increase in indebtedness, particularly to the private sector banks, has reached such proportions as to constitute a possible threat to the stability of the international financial system. Five countries accounted for nearly 70% of the net Eurodallar lending in 1979 (Argentina, Brazil, Liberia, Mexico and South Korea - see Killick, 1981, p. 97). It is in this context that any transition to a less oil-intensive economy will have to take place.

Most of the oil consumed by developing countries is used in the industrial sector (typically 30-50%). The oil price rises and the subsequent "knock-on" effects have raised production costs and have affected the competitive position of many developing countries in international trade. Even though oil only recently replaced coal as the dominant source of the world's commercial energy (in 1973 oil provided 51% of the world's commercial fuel for the first time), much of the existing stock of technical knowledge on which future technical change will depend is based on the assumption of cheap and reliable sources of oil.

While too much reliance should not be placed on the precise relationship between the growth of gross national product and energy consumption, it is difficult to see how developing countries' need for oil will not rise in the coming years. If this need is not met, growth of the industrial sector will suffer. A slowing down of the rate of industrialisation will inevitably mean that less of the surplus labour in rural areas can be absorbed by the modern industrial sector.

The other main user of oil in developing countries is the transport sector (typically 25-30%). Here the energy use is considerably skewed towards the richer sections of the population and to private transport systems. But even so, higher oil prices result in higher freight costs and a considerable reduction in the movement of goods and services. Examples can be quoted of agricultural extension services and mobile health services being severely curtailed through lack of fuel. For instance, Zambia's agricultural extension services are said to have to operate in 1980 with one-fifth of the fuel they used in 1970.

The rural sector of developing countries has been largely protected from the direct effects of oil price rises simply because little commercial energy is used in these areas. The World Bank suggests that both direct and indirect uses of energy in "agriculture typically accounts for less than 5% of a country's commercial energy" (IBRD, 1980, p. 53). However, quite large variations can be found about such an average; for instance, the direct and indirect use of energy in agriculture is of the order of 20% of commercial energy used in Bangladesh (from Islam, 1980). But even if the amounts are small, commercial sources of energy do play an important role in the rural sector by providing crucial inputs to irrigation pumping, illumination, transport, fertilizer, and agricultural mechanisation. Indeed, in welfare terms, the marginal return to the use of commercial energy in the rural sector might be expect to exceed that in the industrial sector. It may be argued that even at considerably higher prices the use of oil-based products such as fertilizer would still be financially profitable to many rural people (IBRD, 1980, p. 53). In addition to the direct effect, oil price rises also impose severe burdens on rural people through indirect mechanisms, such as the shortage of foreign exchange resulting from the increased bill for oil imports, and the rise in cost of all other rural purchases that use oil in their manufacture or transport.

I. THE ENERGY PROBLEMS OF THE THIRD WORLD

A Summary of Issues

The energy problems facing particular countries are not easily or unambiguously specified; a heterogeneous group of countries is involved, information is often inadequate, and there are many points of view. But, in spite of this, a number of features of the 'energy crisis' are now widely agreed. First, the energy problem has two analytically separate components: on the one hand, there are the familiar problems associated with the rise in oil prices which largely affects the urban and industrial sectors of all economies. And on the other hand, there are the equally important problems associated with the inadequate supply of fuels to the rural sector. These rural fuels are mainly fuel wood, crop residues, and cattle dung, and they usually do not enter into the cash economy; even though these non-commercial fuels are the main source of inanimate energy for more than half of the world's population, little is known of the details of their production and use.

It is also generally agreed that neither of these two "energy problems" is a passing problem. As oil resources are depleted, the 'transition' of the world economy from a dependence on oil to other sources of energy is inevitable in the medium term future; even in the short term, the price of oil is likely to rise in real terms by at least 3% per year over the next decade (World Bank, 1980, p. 1). In rural areas, the need for fuels from the biomass is likely to exceed the supply in many parts of the world far beyond the turn of the century (FAO, 1980a).

Further generalisations are possible about which there is a general consensus of opinion. The oil price rises of the 1970s (see Table 1) produced major shocks throughout the world economic system, and not just in the developing countries. But the superior purchasing power of the developed countries meant that developing countries were unable to compete for supplies at the higher prices. Therefore, in the short run at least, the problems of oil for developing countries are problems of the world distribution of the resource as much as an absolute shortage of supplies.

The immediate impact of these changes for developing countries was on their balance of payments and on oil-using industrial and transport sectors. While the rise in oil prices was not the cause of all changes in the 1970s, it certainly exacerbated existing difficulties. The rise in oil prices meant that a greater proportion of foreign exchange earnings had to go to pay for oil imports. For a number of countries, the proportion of merchandise export earnings which was accounted for by oil imports had risen alarmingly; for instance, in 1977 the proportion for Bangladesh was 48%, for Pakistan 33%, Thailand 29%, Brazil 37%, United States 37% (IBRD, 1980, Table 7, World Development Report). This in turn led to a greater burden of debt or a reduced level of investment in development programmes.

Oil price rises also affected the costs of goods produced in developed countries, thus leading to a worsening of the terms of trade facing developing countries. One author suggests that the 40% rise in the price of manufactured goods imported by oil importing developing countries between 1973 and 1975 had an even greater effect on the balance of payments of these countries than oil prices which rose 286% over the same period, because oil imports constituted only 4% of all imports (Killick, 1981, p.93). The world recession further reduced the demand for developing countries' non-oil exports thereby limiting their ability to earn foreign exchange. Added to this, the real value of official aid flows has remained static or has declined